RESULTS OF EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY FOR THE TREATMENT OF UPPER URINARY TRACT STONES

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The treatment results of 697 renal units in 687 patients treated for upper urinary tract stones using a Piezolith 2500 at the Ageo Central General Hospital during the 5-year period between August 1999 and July 2004 were analyzed. The stone-free rate and the success rate were calculated according to the stone size and location. Univariate and multivariate logistic regression analyses were performed to estimate the effect of the patient age, sex, affected side, stone location and stone size on the stone-free rate and the success rate. Overall, the stone-free rate and the success rate at 3 months after treatment were 82.6% and 91.9%, respectively. The stone-free rates in renal and ureteral stones were 60.5% and 88.7%, respectively. The success rates for renal and ureteral stones were 93.6% and 91.6%, respectively. In a univariate logistic regression analysis, patient age and stone size were significant negative factors for both the stone-free rate and the success rate and the stone location in ureter was a significant positive factor only for the stone-free rate. In a multivariate analysis, stone location in the ureter had a positive effect on the stone-free rate, although a negative effect on the success rate. Extracorporeal shock wave lithotripsy for upper urinary tract stones was an effective and safe treatment modality. However, if pre-treatment factors indicate unfavorable outcome, the other treatment options should be considered for the first line therapy.

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Key words : Extracorporeal shockwave lithotripsy, Upper urinary tract stones, Multivariate analysis, Logistic regression

INTRODUCTION

Extracorporeal shock wave lithotripsy (ESWL) is the most widely accepted therapeutic modality for the management of upper urinary tract stones, and commonly recognized as the first choice, especially for the treatment of the stones in the kidney and upper part of the ureter. In some cases, however, the disintegration of the stones is incomplete despite repeated sessions of ESWL and additional treatments such as transurethral lithotripsy (TUL), percutaneous nephrolithotripsy (PNL) or open surgery are required. It is important to analyze ESWL cases to assess which patients are true candidates for ESWL and exclude the patients who should be treated by another method for the first line therapy. In this study, 687 consecutive patients who were treated by ESWL for upper urinary tract stones during the 5 years between August 1999 and July 2004 at Ageo Central General Hospital were analyzed.

METHODS

The treatment results of 697 renal units in 687 patients who were treated by ESWL at Ageo Central General Hospital within 5 years between August 1999 and July 2004 and were followed up for at least 3 months or until the confirmation of a stone-free status were retrospectively analyzed. The clinical records and the X-ray films before and after the treatment were reviewed. The location and size of the stones were assigned according to the criteria of Japanese Urological Association[1)].

The stone disintegrator was a Piezolith 2500, (Richard Wolf, Germany), in which the stone locations were identified using a combination of X-ray and ultrasonography. Patients with renal stones and U1 stones were treated in the supine position. For U2 and U3 stones, a prone position was selected in most cases. The treatment sessions were repeated until the stone-free status was confirmed in plain abdominal X-ray films, residual stones were recognized as insignificant stones, stones expected to pass spontaneously, or unsatisfactory stone disintegration, thus requiring the application of additional treatment was indicated. The treatment results were evaluated by plain X-ray films 3 months after the completion of the sessions. The results were stratified into four groups, that is, stone-free cases, cases with residual stones equal to or less than 4 mm, cases with residual stones larger than 4 mm and cases that required additional treatment such as TUL or PNL because of inadequate disintegration of the stones. The treatment was recognized as being successful when the patients were classified as being either stone-free or cases

Table 1. Patient characteristics

Patient age	18–86 years (Average 50.2)	
Sex	Male 535 (77.9%), Female 152 (22.1%)	
Laterality	Right 281 (40.9%), Left 396 (57.6%), Bilateral 10 (1.5%)	
Stone composition		
Calcium oxalate		56 (63.6%)
Calcium oxalate+calcium phosphate		24 (27.3%)
Calcium phosphate		3 (3.4%)
Calcium oxalate+uric acid		3 (3.4%)
Uric acid		2 (2.3%)
Total		88 (100.0%)

with residual stones equal to or less than 4 mm in size. The patients' characteristics are summarized in Table 1. The treatment results were evaluated for each renal unit, therefore, bilateral patients were regarded as 2 renal units. A total of 1,396 sessions (average of 2.00 sessions per one renal unit) were performed. Univariate and multivariate logistic regression analyses were used for the statistical analysis. The statistical software package was "Dr. SPSS II for Windows, release 11.0.1J". Variable selection in a multivariate analysis was performed by means of the backward stepwise. The effect of the variables was recognized as statistically significant if the p-value was less than 0.05.

RESULTS

The location and size of the objective stones are indicated in Table 2. More than half of all renal stones were larger than 10 mm, whereas most of the ureteral stones were smaller than 10 mm. A total of 67 additional procedures were performed in treatment of 59 renal units (8.5%, Table 3). The most frequently performed procedure was TUL. Eventually, 576 units (82.6%) were stone-free within 3 months after the treatment and 65 units (9.3%) had residual stones smaller than 4 mm. The treatment results of these renal units were considered as success (91.9%). Meanwhile, 11 units (1.6%) had residual stones larger than 4 mm and 45 (6.5%) required additional surgical intervention. The treatment outcome according to the stone location and the stone size were demonstrated in Tables 4 and 5. The stone-free rate for renal stones (R1, R2, R3) was as low as 60.5% (89/147 units), whereas, that for ureteral stones (U1, U2, U3) was 88.7%. The success rate of renal and ureteral stones was both acceptable with the values of 93.6% and 91.6% respectively. With the R3 stones, the stone-free rate was comparable to that of ureter stones and the success rate was the highest among all locations (Table 4). The treatment results for the R3 stones were intermediate between the renal and ureteral stones. In the following analysis, however, R3 stones were included in the renal stones for simplicity of calculation. The stone-free rate and the success rate for stones with the maximum diameter equal to or less than 10 mm were apparently higher than the rest. Complications during or after the sessions which required hospitalization or any medical or surgical interventions are listed in Table 6. The most frequently observed complications were pain in 27 cases (3.9%) followed by high fever over 38.5°C due to urinary tract infection in 14 cases (2.0%). To examine the factors influencing the treatment outcome, univariate and multivariate logistic regression analyses were performed. Table 7 showed the results of a univariate logistic regression analysis. Patient age, sex, affected side, stone location and stone size were included as independent variables. Sex, laterality and location were treated as categorical data and the value of 0.0 was applied to females, right and kidney and 1.0 to males, left and ureter as dummy variables. The patients' sex and affected side were not predictive variables for either the stone-free rate or the success rate. The patient age and stone size had a negative impact on both the stone-free rate and the success rate. Stone location in the ureter was a significant positive factor for the stone-free rate, however, had no significant impact on the success rate. Table 8 shows the result of multivariate logistic regression. The patient age and stone size were also significant predictors both for the stone-free rate and the success rate. A stone location in the ureter was a positive factor for the stone-free rate, whereas, it was significantly negative for the success rate.

DISCUSSION

ESWL is currently the most widely accepted modality for the treatment of upper urinary tract stones. Stone

Table 2. Stone size and location

Stone size (mm)	Location							Total
	R1	R2	R3	U1	U2	U3	2 locations	
≤4	0	2	0	37	2	10	1	52
5–10	1	41	11	303	14	71	2	443
11–20	1	56	15	86	5	15	0	178
21–30	0	8	4	4	0	0	0	16
>30	0	8	0	0	0	0	0	8
Total	2	115	30	430	21	96	3	697

Table 3. Additional treatment

Additional treatment	Number of the patients (%)
TUL before the ESWL	5 (0.7)
TUL between the ESWL sessions	6 (0.9)
TUL after the ESWL	36 (5.2)
PNL before the ESWL	2 (0.3)
PNL between the ESWL sessions	2 (0.3)
PNL after the ESWL	2 (0.3)
PNS before the ESWL	8 (1.1)
PNS between the ESWL sessions	2 (0.3)
PNS after the ESWL	1 (0.1)
Ureteral stent insertion before the ESWL	3 (0.4)
Total	67 (9.6)

PNS, percutaneous nephrostomy.

disintegration is available on an outpatient basis with only a minimal number of unfavorable complications. In contrast, the recent advances in endourological techniques and devices have provided the comparable alternative to the ESWL. TUL, at present, is a safe and painless procedure which provides an excellent stone-free rate without any major complications especially for lower ureteral stones[2]. A PNL sometimes saves the time and the treatment cost in the management of complicated large renal stones[3]. In most cases with renal or upper ureteral stones, ESWL is undoubtedly the first choice of treatment. In some cases, however, selecting other methods than ESWL may save both time and treatment cost, while also avoiding unnecessary stress by the patients. Therefore, an evaluation of the treatment efficacy of ESWL according to various pretreatment conditions is of great importance.

In the present study, the treatment results of ureteral stones were better than renal stones when evaluated by the stone-free rate. In contrast, the treatment of renal stones provided better results in the success rate though the difference was not significant based on a univariate analysis. The discrepancy of the results between the univariate analysis and multivariate analysis could be explained by the strong correlation between the stone location and stone size. The median value of maximum diameter was 12 mm in renal and 8 mm in ureteral stones ($p<0.001$; Mann-Whitney U test). This difference is not incomprehensible because stones with a diameter of less than 4 mm may cause symptoms which thus require early intervention when existing in the ureter. When evaluated by a univariate analysis, the results of the renal stones were not as good as expected because the renal stones were larger than the ureter stones. On the other hand, a multivariate analysis including both the stone size and locations as independent variables could estimate the potential effect of the stone locations by equating the stronger effect of the stone size. If the stones of the same size exist in kidney and ureter of different patients, success rate would thus be better for renal stones. Considering the results of both univariate and multivariate analyses, the conclusion is that renal stones resulted in a better success rate, however, renal stones also produced more residual stones.

Residual stones are one of the major problems after ESWL treatment. The term clinically insignificant

Table 4. Treatment outcome according to the stone location

Locations	Stone-free	Residual stones ≤4.0 mm	Residual stones >4.0 mm	Required additional treatment	Total
R1	1 (50.0)	1 (50.0)	0 (0.0)	0 (0.0)	2 (100.0)
R2	63 (54.8)	44 (38.3)	5 (4.3)	3 (2.6)	115 (100.0)
R3	25 (83.3)	3 (10.0)	0 (0.0)	2 (6.7)	30 (100.0)
U1	385 (89.5)	11 (2.6)	3 (0.7)	31 (7.2)	430 (100.0)
U2	17 (81.0)	1 (4.8)	1 (4.8)	2 (9.5)	21 (100.0)
U3	83 (86.5)	4 (4.2)	2 (2.1)	7 (7.3)	96 (100.0)
2 locations	2 (66.7)	1 (33.3)	0 (0.0)	0 (0.0)	3 (100.0)
Total	576 (82.6)	65 (9.3)	11 (1.6)	45 (6.5)	697 (100.0)

Table 5. Treatment outcome according to the stone size

Stone size (mm)	Treatment outcome, number of patients (%)				
	Stone-free	Residual stones ≤4.0 mm	Residual stones >4.0 mm	Required additional treatment	Total
≤4	46 (88.5)	3 (5.8)	1 (1.9)	2 (3.8)	52 (100.0)
5–10	392 (88.5)	24 (5.4)	5 (1.1)	22 (5.0)	443 (100.0)
11–20	126 (70.8)	29 (16.3)	5 (2.8)	18 (10.1)	178 (100.0)
21–30	11 (68.8)	4 (25.0)	0 (0.0)	1 (6.3)	16 (100.0)
>30	1 (12.5)	5 (62.5)	0 (0.0)	2 (25.0)	8 (100.0)
Total	576 (82.6)	65 (9.3)	11 (1.6)	45 (6.5)	697 (100.0)

Table 6. Complications

Complications	Number of patients (%)
Pain	27 (3.9)
Urinary tract infection	14 (2.0)
Hematuria	2 (0.3)
Palpitation	1 (0.1)
Hyperventilation syndrome	1 (0.1)
Total	45 (6.5)

residual fragment (CIRF) is used to describe the small residual stones which might not cause any clinical symptoms. Usually, they are defined as residual stones that are smaller than 4 mm in size, asymptomatic, non-obstructive, non-infectious and associated with sterile urine[4]. Tan et al.[4] reviewed the literature while addressing the management of CIRF. The stone-free rate after a follow up period of 15 to 40 months ranged from 23.8% to 46.5%. The rate of stone re-growth was observed to range from 2.0 to 37%. With this diversity in the results, the conclusions of each author were different. Some authors indicated that CIRF should be observed without any treatment[5], and additional procedures to clear the fragments are not necessary. In contrast, other researchers have argued that the term CIRF is not appropriate and they thus recommended additional treatment to obtain the stone-free status[6]. ESWL has a harmful effect on the kidney itself and its surrounding organs[7]. Furthermore, a recent report demonstrated that the risks of diabetes mellitus and hypertension are increased after shock wave therapy[8]. One suggestion to resolve these contradictory problems is the application of medical treatment after ESWL[9-11] and physical exercise to promote the spontaneous passage of the stones[12]. Kenneth et al.[12] demonstrated the efficacy of mechanical percussion, patient inversion and urinary diuresis for residual lower pole fragments after shockwave stone therapy. This would not only prevent the recurrence of stones but also help to avoid the unnecessary long term complications caused by repeated sessions of ESWL.

In the present series, both a univariate and multivariate analysis demonstrated the patient age to have a significantly negative effect on the stone-free rate and the success rate. Abe et al.[13] analyzed the outcomes of ESWL and factors having an impact on the achievement of stone-free status and on the success rate. The stone location and size, number of stones, history of urolithiasis and the patient age were significant factors. The authors assumed that the stone-free rate is higher in children than in adults because children have a shorter, more elastic and distensible ureter and a low damping effect when undergoing shockwave energy. Abdel-Khalek et al.[14] analyzed the results of ESWL for renal stones in 2,954 patients using multivariate logistic regression. The patient age, stone size, location, the number of the stones, radiological renal picture and congenital anomalies had a significant impact on the stone-free rate. The stone-free rate in the patients with the age equal to or less than 40 and age more than 40 were 89% and 84%, respectively ($p < 0.001$). In the present study, the parameters representing body mass such as body weight or body mass index (BMI) which are correlated with the patient age, were not included in the independent valuables. Ackermann et al.[15] reported the result of multivariate analysis including both

Table 7. Univariate logistic regression

			Stone-free rate			Success rate		
			Regression coefficient (B)	Wald statistics	P value	Regression coefficient (B)	Wald statistics	P value
Age	Mean	50.1	−0.027	12.185	0.000	−0.033	7.826	0.005
	SD	13.5						
Sex	Male (1.0)	542	0.156	0.434	0.510	0.514	2.342	0.126
	Female (0.0)	152						
Laterality	Left (1.0)	405	0.166	0.671	0.413	0.025	0.007	0.935
	Right (0.0)	289						
Location	Kidney (0.0)	147	1.629	56.849	0.000	−0.807	2.781	0.095
	Ureter (1.0)	547						
Size	Median	8	−0.101	30.193	0.000	−0.053	7.279	0.007
	Range	2–65						

Table 8. Multivariate logistic regression

	Stone-free rate			Success rate		
	Regression coefficient (B)	Wald statistics	P value	Regression coefficient (B)	Wald statistics	P value
Age	−0.027	10.498	0.001	−0.031	6.713	0.010
Location	1.276	26.825	0.000	−2.124	8.950	0.003
Size	−0.057	8.671	0.003	−0.104	15.480	0.000

age and BMI as independent variables. Their result was contradictory to the present findings with regard to the patient age. In their series, increasing age had a positive effect on the success rate. They hypothesized that the difference in the stone composition at various ages might play a significant role. The effect of the patient age on the treatment result is still controversial. Decreases in oral fluid intake and diminished physical activity could partially explain the result. Other predictive factors cited in the literature include the CT attenuation value[16], type of the lithotriptor[17] and operator[18].

The factors that influence the treatment outcome of ESWL for upper urinary tract stones were analyzed. Patient age, stone location, stone size had a significant effect on the results of ESWL using a Piezolith 2,500. Other treatment options should therefore be considered if the patient's pretreatment condition thus indicates a lower expectancy of total stone clearance.

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和文抄録

体外衝撃波砕石術による上部尿路結石の治療成績

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1999年８月から2004年７月までの５年間に上尾中央総合病院で Piezolith 2500 を用いて体外衝撃波腎尿管砕石術を施行された687症例，697腎尿管の治療成績を検討した．結石の大きさ，部位による完全排石率と有効率を算出した．患者の年齢，性別，患側，結石の部位，結石の大きさの完全排石率，有効率に対する影響を推定するため単変量および多変量ロジスティック回帰分析を行った．全症例での３カ月後の完全排石率および有効率はそれぞれ82.6％および91.9％であった．腎結石および尿管結石での完全排石率はそれぞれ60.5％および88.7％であった．腎結石および尿管結石での有効率はそれぞれ93.6％および91.6％であった．単変量ロジスティック回帰分析では患者の年齢と結石の大きさが完全排石率，有効率の両方を低下させる要因であった．結石が尿管にあることは完全排石率のみを有意に改善させる要素であった．多変量解析では結石が尿管にあることは完全排石率を改善させるが，有効率は低下させる要因であった．体外衝撃波砕石術は上部尿路結石に対する有効で安全な治療法である．しかし，治療前の要因から好ましくない結果が予想される場合は他の治療法を検討すべきと思われる．

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